REMARKS/ARGUMENTS

In response to the Office Action mailed May 17, 2006, Applicants request reconsideration. Claims 1-10 are pending in this patent application.

Claims 1 and 3 are the two pending independent claims and each of those claims is again discussed separately.

Claim 1 is directed to a semiconductor laser device including an active layer. The light produced by the semiconductor laser is generated in the active layer through the recombination of charge carriers. As is conventional in semiconductor lasers, the semiconductor laser according to claim 1 includes cladding layers on opposite sides of the active layer. One of those cladding layers is designated a lower cladding layer on a first side of the active layer. Rather than a single cladding layer on the opposite side of the active layer, a more complex structure is present. That more complex structure includes a first upper cladding layer, an etching stopper layer, and a second upper cladding layer, arranged serially. Further, the second upper cladding layer includes a stripe protrusion. The embodiment of Figure 2 of the patent application includes a lower cladding layer 2, an active layer 3, a first upper cladding layer 4, an etching stopper layer 5, and a second upper cladding layer 7.

An important feature of the invention as defined by claim 1 and clarified in the previous response is that the etching stopper layer is a material "including a chemical element different from the chemical elements of each of said lower, first upper, and second cladding layers...". This language of the claim is believed to be entirely clear in stating that at least one of the chemical elements found in the etching stopper layer is not found in any of the lower, first upper, and second upper cladding layers. In spite of the apparent clarity of this description, the Office Action mailed May 17, 2006 seems to have confused and inverted this language in maintaining an improper rejection.

According to claim 1, the semiconductor laser also has particular refractive index relationships between particular layers. The etching stopper layer has a refractive index that is within a range of $\pm$ five percent of the refractive index of each the lower, first

upper, and second upper cladding layers. This feature has not been shown to be present in the prior art applied in rejecting claim 1.

Claims 1-3 and 7-10 were again rejected as obvious over Murayama (U.S. Patent 6,424,668) in view of Shima et al. (U.S. Patent 5,420,066, hereinafter Shima). This rejection is not only again respectfully traversed, but questioned as to form. The same question as to form was raised in the response filed February 21, 2006, but, like other issues raised, received no response or apparent attention from the Examiner.

Claims 9 and 10 do not depend from claim 1 and should not be rejected in the same rejection made with respect to claim 1, but should be rejected in combination with the rejection of claim 4. While the same publications were relied upon in rejecting claims 4-6 as rejecting claims 1-3 and 7-10, the reasoning of the rejections is different because the two independent claims are different. The Examiner is encouraged to correct the rejection with respect to claim 1 and its dependent claims, although the rejection merely pertains to form, in view of the high probability of an appeal of the final rejection.

In the final rejection the principal comments concerning the rejection of claims 1-3 and 7-10 were a verbatim reproduction of the comments appearing in the Office Action mailed August 24, 2005. Only the single paragraph appearing at page 4 of the Office Action indicated any consideration of the claim amendment that had been made in the response filed February 21, 2006. According to that paragraph,

> "Applicant's [sic] argue that the etch stop layer of Murayama does not include a different chemical composition then [sic] the cladding layers since it does include the materials that are in the cladding layers. This is erroneous since the cladding layers include InGaAlP and the etch stop layer contains InGaP, even though the etch stop does contain **some** of the same materials as the cladding layer[,] it does have a different chemical composition then [sic] the cladding layer since it does not include Al. Therefore the rejection stands." (Emphasis original.)

With respect, apparently the language of claim 1, as amended, was not understood. There is no reference to chemical compositions in the amended claim 1, there is a reference to chemical elements. It is understood in the relevant arts that chemical elements mean the elements as described in the Periodic Table of Elements. Composition

implies and the comments refer to compounds, not to elements. Therefore, it would appear that a fundamental error occurred in understanding the amended claim 1 that was presented.

As to the different chemical element feature of claim 1, no suggestion can be found in the prior art through the hypothesized modification of Murayama with Shima, to meet the language of the amended claim.

Murayama, as accurately characterized in the final rejection, describes a semiconductor laser including an active layer of GaInP (and AlGaInP, although not mentioned in recent Office Actions) and a lower and first upper cladding layer of AlGaInP. Further, an etch stop layer 24 on the first upper cladding layer 22 is InGaP. The second upper cladding layer 26, like the first upper cladding layer 22, is AlGaInP. The chemical elements in the etching stopper layer are In, Ga, and P. The chemical elements in the lower, first upper, and second upper cladding layers are Ga, In, P, and Al. Therefore, there is no chemical element in the etching stopper layer that is different from the chemical elements of the lower, first upper, and second upper cladding layers of Murayama.

Of course, the Examiner did not rely entirely on Murayama in asserting that the previous form of claim 1 was unpatentable as obvious. Reliance was also placed upon Shima with an assertion that one of skill in the art would have modified the Murayama laser by replacing the InGaP etching stopper layer of Murayama with the AlGaAs etching stopper layer of Shima. Applicants agree that if this substitution were made, then the etching stopper of the hypothetical product of the modification would contain an element, namely As, not present in the lower, first upper, and second upper cladding layers of the Murayama laser. However, as previously pointed out, the substitution has been hypothesized in a vacuum without giving consideration to relevant factors, such as whether the hypothesized modification would be suggested to one of skill in the art from the two publications.

Simply plucking one material from a complex semiconductor device made of specific materials and inserting that material in replacement of an existing different material in another semiconductor laser does not take into account technological factors

well known to that person of ordinary skill in the art. These technological factors may, in some instances, relate to the chemical processes in which the materials are deposited, may relate to the properties of the materials, such as likelihood of oxidation when employing aluminum-containing materials, and always considers as relevant factors energy band gaps and lattice constants of adjoining materials. It is known to any person of ordinary skill in the semiconductor laser arts that whenever two dissimilar materials are brought into contact with each other, if the crystalline lattices are mismatched there is resulting strain, and even crystalline dislocations, that can seriously interfere with or destroy the desired current flow across the interface between the two materials. Further, when the energy bandgaps of the materials are different, the band structure at the interface may include discontinuities resulting in serious interruptions of charge carrier flows. Both lattice mismatches and energy band discontinuities can prevent the structure from functioning as a semiconductor laser or even from producing incoherent, i.e., non-laser, light. For these reasons, one cannot consider obvious the substitution of Shima's AlGaAs layer for the InGaP layer of Murayama without evaluating other factors. Those other factors show that in this instance there is no motivation for the substitution hypothesized here.

Shima is particularly helpful in explaining one such point which must be considered in determining obviousness here. In Shima, an etching stopper layer of a II-VI material is replaced with III-V material. Further, that III-V material of the etching stopper layer is identical in constituents, although not in composition, with the cladding layers contacted by that etching stopper layer. Those layers are all AlGaAs with a relative aluminum content of the etching stopper layer greater than 0.6 and in a range of 0.38 to 0.6 in the adjacent cladding layers. This difference in composition takes advantage of differential chemical etching properties that, for a particular etchant, depend upon aluminum content of the respective layers. See the description in column 8 of Shima. In addition, it is well known in the art that the lattice constants of AlAs and GaAs are very similar and the similarity of composition of the two layers means that the bandgap discontinuity between the two layers is also minimized. For the Examiner's assistance, a graph showing the relationship of lattice constants and bandgap energies for

numerous compound semiconductor materials from *High-Speed Semiconductor Devices*, edited by Sze (1990) is attached. Also attached are tables showing lattice constants and bandgap energies for many of the same semiconductor materials, taken from *Physics of Semiconductor Devices* by Sze (1981), providing support for what appears in Shima. By contrast, the AlGaInP cladding layers of Murayama and the GaInP etching stopper layer of Murayama are alloys of compound semiconductor materials (AlP, GaP, and InP) having substantially varying lattice constants and energy bandgaps. That lattice constant and bandgap energy information for those alloy constituents, taken from the attachments, appears in summary form in the following table.

Material	Lattice Constant (A)	Bandgap Energy (eV)
AlP	5.45	2.4
GaP	5.45	2.26
InP	5.87	1.35
GaAs	5.65	1.42

It is clear from the foregoing table that simply replacing the GaInP etch stopping layer of Murayama with the AlGaAs etching stopper layer of Shima raises substantial issues concerning composition of the AlGaAs to achieve some kind of compromise, if even possible, with respect to lattice mismatch and potential energy bandgap discontinuities, not even considering processing conditions, such as the ability to etch one layer differentially with respect to another.

In the absence of information showing that the substitution would readily be made by one of skill in the art, the foregoing information demonstrates that the substitution of part of Shima into the Murayama structure would not have been an obvious modification to one of ordinary skill in the art and therefore *prima facie* obviousness has not and cannot be demonstrated without further information not yet produced. The rejection is erroneous and, upon reconsideration, should be withdrawn as to this feature of claim 1 without the necessity of considering other differences between claim 1 and the prior art.

Of course, two important features are present in claim 1 and both features provide, in combination, the advantages of the semiconductor laser described in the patent application. That second feature relates to the refractive indices of the particular layers and requires that the etching stopper layer have a refractive within a range of five percent of the refractive indices of the three cladding layers. The Examiner asserted, in the last two Office Actions, in identical language at page 3 of each of those Office Actions, that this refractive index limitation is described in Murayama and/or Shima. However, there was no citation of any specific passage of either patent as to where this disclosure appeared. Further, there was no reply in the Office Action including the final rejection with regard to the traversal in the previous Amendment as to the absence of such disclosure in either patent. Therefore, Applicants continue to traverse the Examiner's assertion because it is unsupported by any disclosure in the prior art. In fact, Murayama is silent concerning the refractive index relationships of the layers in his semiconductor laser and supplies no reason for limiting that relationship as described in claim 1. Shima is likewise silent so that this ground of rejection is clearly erroneous and should be withdrawn.

For the two independent reasons described above, *prima facie* obviousness of claim 1 and its dependent claims 2, 3, 7, and 8 has not been established. Upon reconsideration, the rejection of those claims should be withdrawn.

The semiconductor laser device according to claim 4 differs from the semiconductor laser according to claim 1 in several important respects. First, the second upper cladding layer is located on and in contact with the first upper cladding layer so that there can be no etching stopper layer interposed between those two cladding layers. Second, the second upper cladding layer has a different material from the first upper cladding layer and has a refractive index within five percent of the refractive index of the first upper cladding layer.

An embodiment of the invention consistent with and encompassed by claim 4 is illustrated in Figure 3 of the patent application. The embodiment of Figure 3 differs from the embodiment of Figure 1 by the absence of the etching stopper layer 5 that appears in

Figure 1 as well as by the specified difference n composition, a difference not susceptible to illustration in Figures 2 and 3.

Claims 4-6 and, presumably claims 9 and 10, were rejected as obvious over the same combination of Murayama in view of Shima. This combination and the resulting rejection are again traversed.

No explanation was provided in the Office Action mailed May 17, 2006 as to why the previous rejection of claim 4 was maintained. In fact, there was no comment at all on the amendment of the final paragraph of that claim 4 which eliminated the possibility of an etching stopper layer being interposed between the first and second upper cladding layers.

In order for Murayama in view of Shima to suggest claim 4, the etching stopper layers, essential elements in the two semiconductor laser of Murayama and Shima, would have to be eliminated. The fact that both of the Murayama and Shima laser structures include those layers and the important role of those layers in preparing the semiconductor lasers described in the two patents, demonstrates clearly that no suggestion can be found in either patent for removing the etching stopper layers. In other words, it is impossible for any combination of Murayama and Shima to suggest the invention as defined by claim 4 and its dependent claims.

Further, there has never been any demonstration that either Murayama or Shima describes the refractive index relationship specified in the final lines of claim 4. In rejecting claim 4, the Examiner merely reiterated the same unsupported assertion applied in rejecting claim 1, namely that the refractive index range of the claim is disclosed at unspecified locations within some combination of Murayama and Shima. Because the patents are silent concerning quantitative relationships between refractive indexes of particular layers there can be no suggestion for the second important feature of claim 4 in the prior art applied. The rejection is, on this separate ground, plainly erroneous and should be withdrawn as to claim 4 and all of its dependent claims, claims 5, 6, 9, and 10.

Claim 4 further requires that the materials of the first and second upper cladding layers be different in composition. The Examiner has never addressed this limitation of claim 4. The prior art structures described by Murayama and Shima all describe first and

second upper cladding layers that are not only separated by an etch stopping layer but also that are identical in composition. There is no description nor suggestion that the two upper cladding layers should have different compositions. Therefore, no combination or modification of Murayama and Shima, no matter how made, can disclose this feature of claim 4 and make that claim, and dependent claims 5, 6, 9, and 10, obvious.

Reconsideration and allowance of all claims now pending are earnestly solicited.

Respectfully submitted,

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HIGH-SPEED SEMICONDUCTOR DEVICES

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10^{-5}	Cadmium	2×10^{-7}
10^{-5}	Indium	1×10^{-7}
10^{-6}	Mercury	8×10^{-8}
0^{-6}	Selenium	5×10^{-8}
0^{-7}	Tellurium	1×10^{-9}

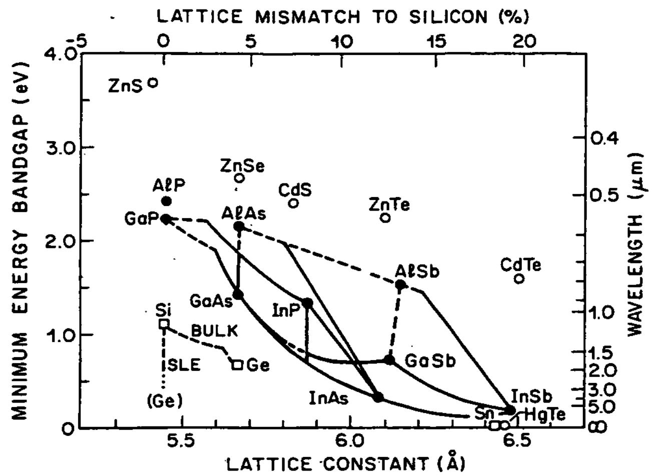

Fig. 7 Compilation of minimum bandgap versus lattice constant data for the column IV, III-V, and II-VI semiconductors. Right axis indicates the wavelengths of light that would be emitted by a laser or LED for a material of the corresponding bandgap. For the column IV and III-V materials, connecting lines give information for alloys of the materials at the endpoints of a given line segment. Solid lines indicate a direct bandgap and dashed lines an indirect bandgap. For Ge-Si, the line denoted BULK corresponds to unstrained, lattice-mismatched growth and the line SLE to strained layer epitaxy of GeSi on unstrained Si. (After Ref. 13)

λ (in μm) $= 1.24/E_g$ (in eV). Below this wavelength a semiconductor will begin to absorb light and a direct-bandgap material to emit light. If different III-V materials can be combined as an alloy, the points are connected by lines indicating the bandgap of the alloy with a solid line denoting a direct bandgap and a dashed line an indirect bandgap. However, these alloy lines should be used with a bit of caution: they indicate the bandgap an alloy should have but do not indicate whether that alloy can be synthesized. Many compositions may be thermodynamically unstable and will spontaneously form precipitates or regions of differing composition. These thermodynamically unstable regions are known as miscibility gaps and are identified in the thermodynamic literature.[14] Note that, in the literature, an alloy such as GaAs-AlAs is generally denoted by $Al_xGa_{1-x}As$, where the column III (or II) specie(s) are on the left in alphabetical order, the column V (or VI) specie(s) on the right, and x or y denote the composition fraction of the chemically interchangeable atoms.

The semiconductor families are then defined by those materials that share the same lattice constant (i.e., on a vertical line) or by materials that may be combined, as alloys, to lattice match a third material. For such alloys, the lattice constant can be approximated by a linear interpolation between the values of the constituents (e.g., an alloy of 47% gallium arsenide and 53% indium arsenide will lattice match indium phosphide). The one added qualification is that fami-

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Physics of Semiconductor Devices

SECOND EDITION

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Appendix F

Lattice Constants

	Element or Compound	Name	Crystal[a] Structure	Lattice Constant at 300 K (Å)
Element	C	Carbon (diamond)	D	3.56683
	Ge	Germanium	D	5.64613
	Si	Silicon	D	5.43095
	Sn	Grey Tin	D	6.48920
IV–IV	SiC	Silicon carbide	W	$a = 3.086$, $c = 15.117$
III–V	AlAs	Aluminum arsenide	Z	5.6605
	AlP	Aluminum phosphide	Z	5.4510
	AlSb	Aluminum antimonide	Z	6.1355
	BN	Boron nitride	Z	3.6150
	BP	Boron phosphide	Z	4.5380
	GaAs	Gallium arsenide	Z	5.6533
	GaN	Gallium nitride	W	$a = 3.189$, $c = 5.185$
	GaP	Gallium phosphide	Z	5.4512
	GaSb	Gallium antimonide	Z	6.0959
	InAs	Indium arsenide	Z	6.0584
	InP	Indium phosphide	Z	5.8686
	InSb	Indium antimonide	Z	6.4794
II–VI	CdS	Cadmium sulfide	Z	5.8320
	CdS	Cadmium sulfide	W	$a = 4.16$, $c = 6.756$
	CdSe	Cadmium selenide	Z	6.050
	CdTe	Cadmium telluride	Z	6.482
	ZnO	Zinc oxide	R	4.580
	ZnS	Zinc sulfide	Z	5.420
	ZnS	Zinc sulfide	W	$a = 3.82$, $c = 6.26$
IV–VI	PbS	Lead sulfide	R	5.9362
	PbTe	Lead telluride	R	6.4620

[a]D = Diamond, W = Wurtzite, Z = Zincblende, R = Rock salt.

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Appendix G

Properties of Important Semiconductors

Semiconductor		Bandgap (eV) 300 K	Bandgap (eV) 0 K	Mobility at 300 K (cm^2/V-s)[a] Elec.	Mobility at 300 K (cm^2/V-s)[a] Holes	Band[b]	Effective Mass m^*/m_0 Elec.	Effective Mass m^*/m_0 Holes	ϵ_s/ϵ_0
Element	C	5.47	5.48	1800	1200	I	0.2	0.25	5.7
	Ge	0.66	0.74	3900	1900	I	1.64[c] 0.082[d]	0.04[e] 0.28[f]	16.0
	Si	1.12	1.17	1500	450	I	0.98[c] 0.19[d]	0.16[e] 0.49[f]	11.9
	Sn		0.082	1400	1200	D			
IV–IV	α-SiC	2.996	3.03	400	50	I	0.60	1.00	10.0
III–V	AlSb	1.58	1.68	200	420	I	0.12	0.98	14.4
	BN	~7.5				I			7.1
	BP	2.0							
	GaN	3.36	3.50	380			0.19	0.60	12.2
	GaSb	0.72	0.81	5000	850	D	0.042	0.40	15.7
	GaAs	1.42	1.52	8500	400	D	0.067	0.082	13.1
	GaP	2.26	2.34	110	75	I	0.82	0.60	11.1
	InSb	0.17	0.23	80000	1250	D	0.0145	0.40	17.7
	InAs	0.36	0.42	33000	460	D	0.023	0.40	14.6
	InP	1.35	1.42	4600	150	D	0.077	0.64	12.4
II–VI	CdS	2.42	2.56	340	50	D	0.21	0.80	5.4
	CdSe	1.70	1.85	800		D	0.13	0.45	10.0
	CdTe	1.56		1050	100	D			10.2
	ZnO	3.35	3.42	200	180	D	0.27		9.0
	ZnS	3.68	3.84	165	5	D	0.40		5.2
IV–VI	PbS	0.41	0.286	600	700	I	0.25	0.25	17.0
	PbTe	0.31	0.19	6000	4000	I	0.17	0.20	30.0

[a] The values are for drift mobilities obtained in the purest and most perfect materials available to date.
[b] I = indirect, D = direct.
[c] Longitudinal effective mass.
[d] Transverse effective mass.
[e] Light-hole effective mass.
[f] Heavy-hole effective mass.

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